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China's new energy vehicle policies: Evolution, comparison and recommendation

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ABSTRACT

Environmental impact and climate change urge governments across the globe to prioritize to the development of new energy vehicles (NEVs). Since 2010, the Chinese government has introduced numerous policies to accelerate the development of the NEV industry. These policies have various effects on NEVs due to several complex factors, such as timing, regional economies, and other demands on the government's attention. This paper investigates NEV policies that were launched by China's national, provincial, and municipal authorities from 2010 to 2016 in terms of their similarities and differences, as well as their successes and failures. By doing so, we trace the evolution of Chinese NEV policies and compare them, in order to advise on the policies that are most beneficial to the future development of the Chinese NEV industry. The main results are as follows: (1) the implementation of NEV policies consisted of a "plan-pilot-promotion-subsidy-development" process; (2) the coordination mechanisms of central and local governments should be strengthened; (3) future policies should focus on infrastructure construction, research and development (R&D), the recycling of batteries, and private purchase regulations. This paper contributes to policy-making in Chinese NEV industry.

1. Introduction

To maintain its rapid economic development, China currently heavily relies on energy resources, the supply of which has been contracted (Guan et al., 2008). Despite a steady economic growth, an increase in externally-sourced oil reliance is evident, along with China's unreasonable energy consumption structure (Oliver et al., 2009; Qin et al., 2017) and gradually worsening environmental pollution (Zhang et al., 2013; He and Qiu, 2016). Due to energy consumption; significant greenhouse gases (GHG) emissions are being released into the atmosphere. Since 2009, China has become the world's largest energy consumer; thus, the country's GHG emissions and its contribution to climate change have received increasing attention worldwide in recent years (Zhen et al., 2017).

Energy consumption of transportation sector accounts for one-third of the total energy consumption of the world. Energy saving in transportation sector has received widely concerns. The transportation sector produces significant GHG emissions that are ejected into the natural atmosphere and is a major source of GHG emissions in China. Moreover, this sector emits huge amounts of air pollutants that contribute to health problems (He et al., 2017; Hill et al., 2009). Within the transport sector, road transport is the largest contributor to global warming and air pollutants. Significantly, vehicle exhaust is considered among the largest sources of serious air pollution in China (Yang and He, 2016; Wang et al., 2010). In Beijing, for example, in 2015 vehicle exhaust emissions

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contributed to about 60% of the air pollution (Fan et al., 2017).

The availability of new energy vehicles (NEVs) heralds a breakthrough in automobile energy conservation and environmental protection (Zhang and Bai, 2017; Wang and Dong, 2016). Importantly, NEVs do not rely on fossil fuel. Therefore, NEVs decrease vehicle exhaust emissions, and some even do not produce exhaust emissions (Hao et al., 2014). By transforming economic growth patterns to develop a green economy and low-carbon industries, economic and ecological benefits can be equally prioritized and garnered (Yuan et al., 2015). Therefore, the exploitation and development of NEVs is considering as an alternative technology to cope with the energy and environmental challenges, and has been raised to the strategic level in major vehicle-producing countries (He and Chen, 2013). In November 2015, the cumulative production of Chinese NEVs exceeded 1% of the entire vehicle market. The sales volume of NEVs was 507,000 and 777,000 in 2016 and 2017 respectively, only accounting for 1.81% and 2.69% of the aggregate sales volume of vehicles. Market development was imbalanced, and among 88 pilot cities, the promotion quantity of the last 40 cities accounts for less than 80% of the top five cities. However, the technical innovation and industrial scale of the NEV industry in China still lags behind those of other countries. As yet, China remains in the initial stages of NEV industry development (Xu and Su, 2016). Industrial development was also influenced by other factors such as weak core competitiveness, poor supporting facilities, and conservative consumption habits. As the NEV industry transited from the introduction period to the growth period, policy guidance and support, other than market mechanism, were required (US Department, 2007).

Since 2010, China's government (at all levels) issued many policies designed to support the rapid development of NEVs as a critical strategy for the automobile industry. These policies were intended to allow China to overtake advanced countries, but some problems have certainly lingered (Zhou et al., 2015; Hoen and Koetse, 2014). For example, some production enterprises defrauded the government of subsidy payments, and shut down while still awaiting policy announcements. Consumers could not register their ownership after purchasing their NEVs and found vehicle charging to be a complex process. Additionally, public sector procurement is at a much greater level than that in the private sector.

The industrial policies regarding NEVs are complex and varied. These policies involve complex issues such as the time dimension of NEV industry development, the combination of every type of policy instrument, and the connection and coordination of policies at different levels. The government's science-based approach to industry development policies is intended to be a basic guarantee of facilitating the smooth realization of the targets of NEV planning (Li et al., 2016; Wang et al., 2017). Previous research has mainly focused on specific policies or an analytic framework. These studies, therefore, could not fully explain the existing problems. A lack of multidimensional and systematic research specifically aimed at NEV polices in China still prevails. This paper summarizes the evolution, trend and path of NEV policies at all levels in the temporal context, in order to discover the realistic problems that must be solved. By combining government policy and national planning, we propose policy recommendations that are suitable for the industrial development of NEVs. This study may not only benefit policy-making for industrial development, but also improve China's national energy consumption structure, lower carbon exhaust emission aspirations, and benefit the environment.

The rest of this paper is arranged as follows: In Section 2, we introduce the research background including a literature review and research methods. In Section 3, we define NEVs and their development in China. An analysis of policies for NEVs at all levels is presented in Sections 4 and 5. Accounting for the high frequency of financial subsidy policy applications, a comparative analysis of subsidy policies is illustrated in Section 6. Sections 7 and 8 present policy tendencies and recommendations. Finally, the conclusions are given in Section 9.

2. Research background

2.1. Literature review

In recent years, scholars have studied NEV policies of several countries, using different techniques and tools. These studies can be divided into two groups: macroscopic and medium-microscopic.

In macroscopic studies, scholars study every NEV policy and collect market information in order to completely understand the status of current policies. This allows scholars to compare the policies of different countries, analyze existing problems, and then propose relevant recommendations (Xu and Su, 2016; Zhou et al., 2015; Gong et al., 2013). This kind of research can be used by governments to obtain an insight into the state of the NEV industry, on the other side, may neglect the unique characteristics of and discrepancies between different regions.

Similar to the macroscopic aspect, the medium-microscopic aspect of the NEV industry has also been well studied. Medium-microscopic studies cover almost every aspect of the development of the NEV industry, and have become a hot topic in the field of interdisciplinary research. This type of research provides a powerful reference for governments to develop specific application programs in order to promote NEVs; nonetheless, this method lacks systematic approach. The main topics of the medium-microscopic studies are presented in Table 1.

Scholars have mostly analyzed NEV policies using qualitative methods. Quantitative scale tables are also quite common. Furthermore, some scholars have used automatic text analysis to obtain policy keywords. In this way, they can infer the emphases of different policies.

As NEV research progressed, some scholars designed policy analysis frameworks to study the direction of NEV policies. In addition, more government policy instrument categories exist, such as technology-push and demand-pull (Nemet, 2009; Di Stefano et al., 2012); command-and-control and incentive-based (Wachtmeister, 2013); regulatory and economic (Bergek et al., 2014); upstream investment, market creation, and interface improvement (Taylor, 2008); supply-side, environmental-side, and demand-side (Rothwell and Zegveld, 1981; Steinmueller et al., 2010); government-selection versus market-selection and producer-orientation

Table 1
Main topics of medium-microscopic studies.

Topics	Scholars
Marginal efficiency of subsidies and taxes	Steren et al. (2016) and Bigerna et al. (2017)
Consumer purchases	Zhang et al. (2013), Wang and Dong (2016), Egbue and Long (2012) and Li et al. (2016)
Charging station and power network	Peterson and Michalek (2013) and Shojaabadi et al. (2016)
Innovations of core technologies	Zhao et al. (2015) and Qiu and Wang (2016)
Recycling systems for the waste batteries	Li et al. (2016)
Forecasting of emission reductions potential	Thiel et al. (2010), Guo et al. (2016) and Hofmann et al. (2016)
Real-world driving patterns	Saxena et al. (2014), Wang et al. (2015) and Fan et al. (2017)
Total costs of ownership	Gass et al. (2014)
Potential environmental benefits	Tang et al. (2013)

versus consumer-orientation (Xu and Su, 2016); and macroscopic, demonstration, subsidization, preferential tax, technical support, industry management, and infrastructure (Li et al., 2016) policies. Policies are classified into numerous categories as well. In conclusion, we believe that the expansion and analysis of policies mainly revolve around three aspects of industrial and economic development, namely supply, demand, and the environment.

2.2. Materials and methods

In this study, we used qualitative analysis methods to determine the evolution of policies. We also classified and analyzed the reviewed policies. On the time dimension basis, this study analyzed and summarized NEV policies at Chinese national, provincial, and municipal levels. This analysis revealed the different focuses of policies at different times and in different regions. Furthermore, our methods allowed for the comparison of policies at all the three levels. On the basis of our study, we conclude that the government can further optimize their policies.

To guarantee the authority, representativeness, and reliability of the policies, we conducted a search and selection on the basis of the following principles: (1) the selected policies are closely related to the NEV industry and (2) the retrieved policy types comprise laws, regulations, directives, official notices, advice, urban plans, and announcements. We browsed official government websites for the period 2010–2016 such as the China Automotive Industry Association website, and other websites related to research on NEV industrial development. Ultimately, we collected 126 national policies and 423 provincial and municipal policies.

Our analysis was primarily concerned with two aspects: policy instruments and policy purposes. Policy instruments are classified into three types, supply side, demand side, and environmental-side. Supply-side instruments represent the impetus of policies toward the emerging industry. They include talent training, technical support, capital investment, infrastructure, and public service. Demand-side instruments include government procurement, trade control, market subsidies, pilot demonstrations, and price guidance. These instruments reduce the degree of market uncertainty. Environmental-side instruments include target planning, financial support, tax preferences, regulation control, and property rights protection. Policy purposes include industrialization, research and development (R&D), and application (Peterson and Michalek, 2013). Of the purposed, industrialization refers to controlling policies that cover management methods, codes of conduct, and development planning; R&D refers to policies supporting breakthrough technologies; and application refers to the policies that stimulate the production and sales of NEVs, batteries, and charging facilities, among other equipment.

3. Progress of NEVs in China

In China, NEVs have both broad and narrow definitions. According to the 2009 “Entry management rules for new energy vehicle-manufacturing enterprises and products,” NEVs are vehicles that use unconventional fuels (as opposed to gasoline and diesel) or those that use conventional fuels but with a new vehicle power unit. Integrating advanced power control and driving system technologies, NEVs hold unique characteristics due to their new technologies and structures. In this broad sense, NEVs include electric vehicles, hydrogen-powered vehicles, solar vehicles, and alternative energy source vehicles (such as those that use natural gas or ethanol). However, due to technical limitations, electric vehicles that represent NEVs in the narrowest sense have the largest market share. The NEVs mentioned in the “The development plan for the energy-saving and new energy vehicles industry (2012–2020)” include plug-in hybrid vehicles, pure electric vehicles, and fuel cell vehicles. This is the main definition applied to NEV policies in China.

NEVs are beneficial to Chinese economic development, environmental protection, and national security (Van Vliet et al., 2011; Doucette and McCulloch, 2011; Liu and Kokko, 2013; Li et al., 2014). First, their use reduces fuel consumption, alleviates oil shortage, and balances fuel supply and demand. It also ensures the security of national energy resources, protects the health of residents, and helps achieve the sustainable development of environmental resources. Second, by 2020, NEV is expected to help achieve the goal of reducing carbon dioxide emissions per gross domestic product unit by from 40% to 45% of the international emission reduction commitment (compared with 2005 emission levels). Moreover, NEV use should reduce the amount of urban air pollution caused by the use of fossil fuels. Third, the use of NEVs is conducive to technological innovation and enhances the competitiveness of manufacturing industries and promoting scientific research in the domestic vehicle industry. This includes the development program for national high-tech research (Program 863), which is a major NEV-related project. Lastly, NEV use should help

Table 2
Five development goals for NEV in China.

Goals	Description
Substantial progress in industrialization	By 2020, the production of pure electric vehicles and plug-in hybrid vehicles shall reach 2 million; cumulative production and sales shall exceed 5 million
Improvement in fuel economy	By 2020, the average fuel consumption of passenger cars produced that year shall decrease to 5.0 L per 100 km, and those of energy-efficient passenger cars shall decrease to less than 4.5 L per 100 km
Improvement in technological levels	The technologies of NEVs, power batteries, and key components shall achieve the international advanced level, with the adoption of core energy-saving technologies (such as hybrid power, advanced internal combustion engines, and efficient transmissions)
Substantial enhancement in supporting facilities	The scales of technologies and the production of key components shall meet domestic market demand. Charging facility construction and NEV production shall match the demands for NEVs within key areas
Improvement in the management system	To form a relatively complete technical standards system, an effective management system for NEVs, with regards to marketing, after-sales service, and battery recycling, should be established

facilitate the meeting of domestic demand for vehicles, as well as raising consumer awareness of environmental protection issues, improving China's industrial structure, and promoting social and economic development.

The NEV industry was confirmed as one of the seven emerging strategic industries in 2010, and was categorized in the same year as being in the initial stage of industrial development (Porter, 1990). According to the public goods supply theory and the government intervention theory, during the development of the NEV industry, clear challenges in terms of market failure were the basis for government intervention (Diamond, 2009; Choi and Oh, 2010). These challenges included the high expense of developing core technologies, the risky nature of project investment (Liu and Kokko, 2013), the lack of infrastructure for electric charging (He and Qiu, 2016), and product marketing obstacles resulting from the lack of a green consumption public attitude (Connolly and Prothero, 2008). Government policies can improve the efficiency of resource use and accelerate the development of the industry (Gross and Foxon, 2003), whereas a combination of comprehensive policies is useful for the sustainability of innovation (Kivimaa and Kern, 2016). In contrast, according to the theory of infant industry protection, in order to protect the newly developing NEV industry from strong international brands, measures should be taken to increase the level of national innovation. Such measures could include fiscal subsidies (Al-Alawi and Bradley, 2013; Skerlos and Winebrake, 2010), tax deductions, and tax exemptions (Liu and Kokko, 2013). Government policies will play a key role in the development of the NEV industry.

From 2010 to 2016, China's government (at all levels) implemented many policies that were formulated on the basis of local circumstances and the overall situation. "The development plan for the energy-saving and NEVs industry (2012–2020)" established specific goals on the basis of industrial development, energy efficiency, technical innovation, infrastructure, and management systems. Details of the five development goals are given in Table 2.

The production and sales of NEVs reflect not only the development trends of the vehicle industry and consumer perceptions of NEV products, but also the effects of the implementation of government policies (Krupa et al., 2014). Fig. 1 reveals dramatic changes in the production and sales of NEVs over the past seven years. From 2010 to 2013, the production and sales of NEVs in China increased year-on-year at a steady growth rate. However, the first truly explosive growth in the production and sales of NEVs occurred in 2014, and again in 2015. The development of the NEV industry in those two years occurred at an unprecedented high speed. The reasons for this sudden, rapid growth, we believe, were threefold. First, the major domestic and foreign automobile manufacturers accelerated investment in the NEV market. Second, the substantial sales increase reflected a rise in consumer

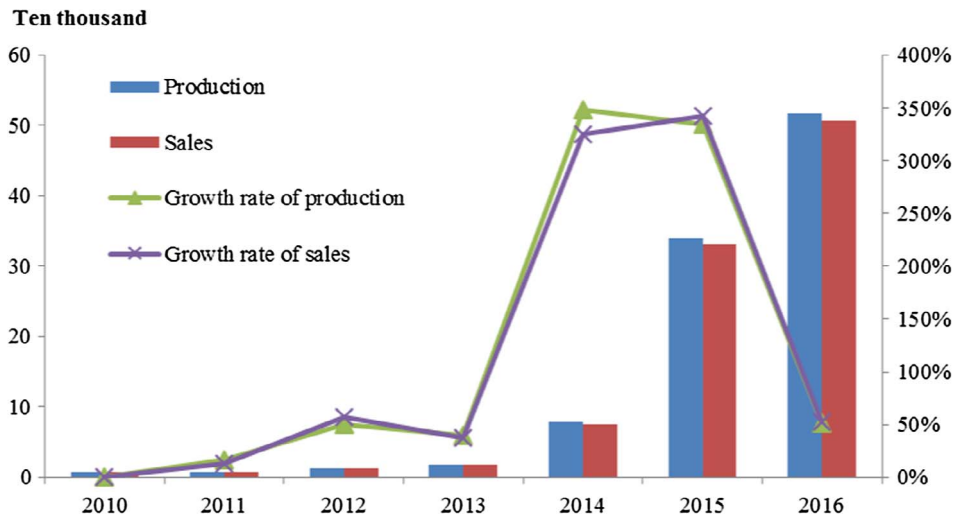

Fig. 1. Variation in annual production and sales of Chinese NEVs, 2010–2016.

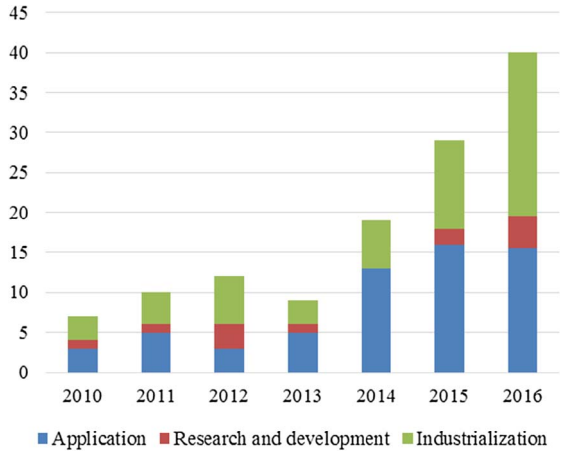

Fig. 2. Number of national NEV policies in China.

acceptance of NEVs. This acceptance reflected an increase in consumer education levels. Third, the marked changes in production and sales directly benefited from many policies, including subsidy policies that supported the development of the NEV industry and were implemented by the Chinese government. Of these three reasons, the impact of government policies on the market was the primary force that drove Chinese manufacturers to produce NEVs and consumers to purchase them.

4. NEV policy at the national level

We collected 126 national NEV policies issued from 2010 to 2016. At first, strategic planning was generally undertaken after considering the entire vehicle industry and on the basis of the goals of energy savings and emission reductions. Next, determining the development route to be followed, along with establishing the guiding ideology of development and pilot cities we selected. Subsequently, through the provision of financial subsidies, individuals were encouraged to purchase NEVs. Once the consumer market was formed, reinforcing the construction of China's charging infrastructure and using innovative financial instruments was necessary to support the NEV industry, in order to accelerate that industry's rapid development.

The NEV industry is managed through the following institutions: The State Council (equivalent to the cabinet in other countries) is the highest decision-making level. The Ministry of Industry and Information Technology implements the plan of industry-integrated management. The National Development and Reform Commission reviews investments. The Ministry of Science and Technology, the Ministry of Environmental Protection, the Ministry of Commerce, the Ministry of Finance, and other ministries also participate in management.

In September 2013, the "Edict on ensuring the popularization and application of new energy vehicles" was issued by the central government. In November 2013, and January 2014, the Ministry of Commerce, the Ministry of Science and Technology, the Ministry of Industry and Information, and the State Development and Reform Commission announced two groups of cities (39 cities in total) in which NEV applications would be promoted. As shown in Fig. 2, since 2010, the number of national policies has increased almost every year. This finding demonstrates the determination and confidence of the Chinese central government in its promotion of the development of NEVs.

The aforementioned policies have encouraged industrial progress. However, NEV R&D has been deficient. Numerous planning-related policies have mandated that R&D be fully supported, but implementation of such policies has not proceeded. In the long term, the quality of NEVs is likely to directly affect demand. Therefore, we should not underestimate the importance of strengthening R&D, as a means to ensure the quality and safety of NEV products.

Fig. 3 maps the keywords extracted from national NEV policies over recent years; the higher the frequency of keywords, the darker is the color. In addition to the keywords "development plan," "emerging industry," and "strategy" at the macroscopic level, national policies included the keywords "product line construction," "safety management," "subsidies verification," and other measures at the medium-microscopic level. National policies had broad coverage and benefited the overall development of the Chinese NEV industry. Other keywords, such as "made in China," "energy-saving," and "air contamination," show that accelerating the development of NEVs would help the entire Chinese manufacturing industry gain an advantageous position in the global market and, significantly, solve resource and environmental problems.

Fig. 4 represents the focuses of national policies regarding the NEV industry by means of instruments and purposes. For industrialization, environmental-side policies are employed to promote the development and application of NEVs. For R&D, supply-side policies are introduced to support R&D institutes and the manufacturers of NEVs and related products, in order to expand technology and product supply. For application, various policy instruments are evenly used, the number of environment-side policies is relatively large, and financial subsidy policies are most common. Fig. 4 illustrates that the NEV industry currently remains in the initial stage of national cultivation (at the macroscopic level).

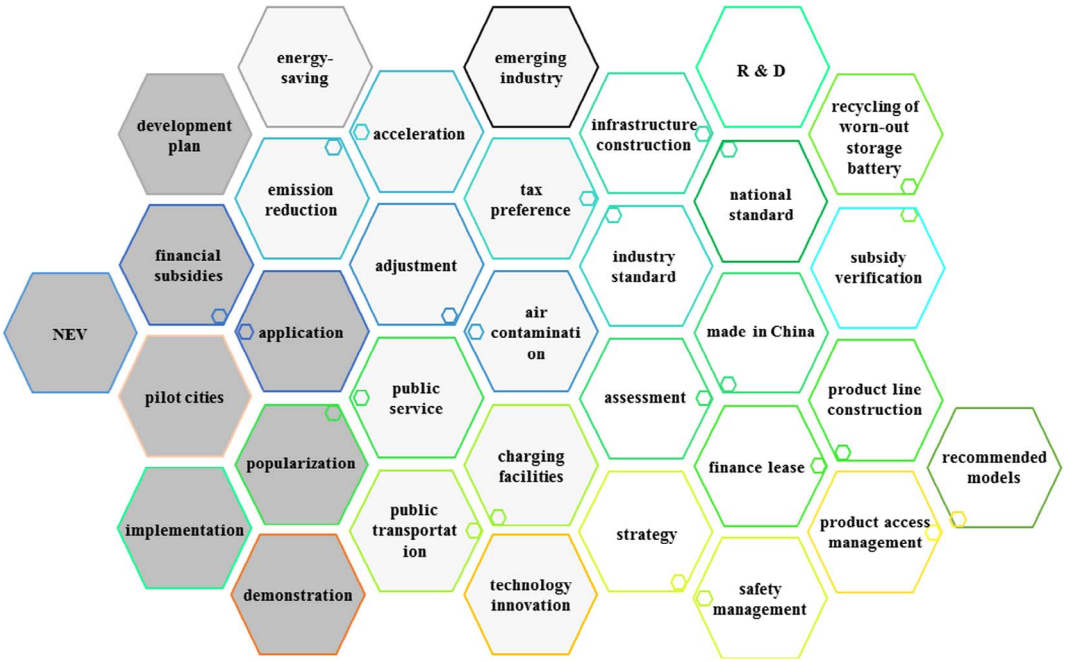

Fig. 3. Map of keywords concerning Chinese NEV policies.

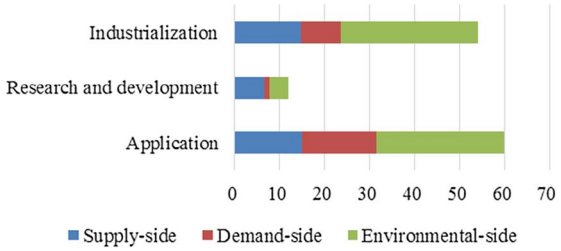

Fig. 4. Classification of national NEV policies.

5. NEV policy at provincial/municipal levels

5.1. Provincial policies for NEVs

Adhering to central government policies, numerous of Chinese provinces have issued their own NEV policies. We collected, summarized, and analyzed 201 policies from 30 provinces and four centrally-administered municipalities (Beijing, Shanghai, Tianjin, and Chongqing), operating directly under the central government. We selected Guangdong and Jiangsu Provinces, and the municipalities of Beijing and Shanghai as samples, because the NEV policies in these areas are more extensive, compared with those in

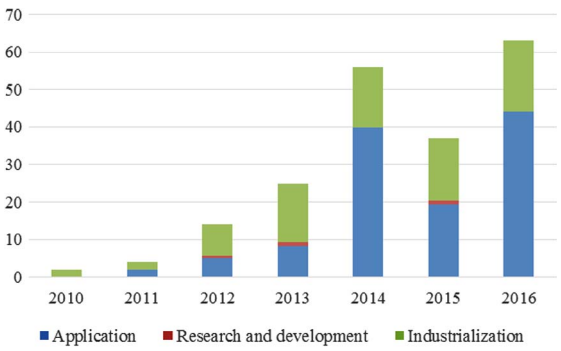

Fig. 5. Number of provincial NEV policies in China.

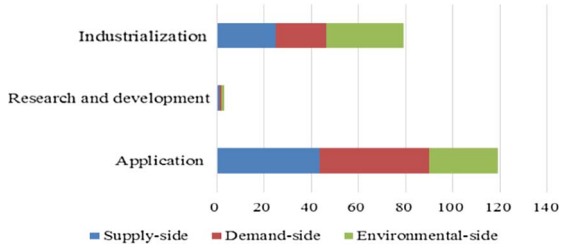

Fig. 6. Classification of provincial NEV policies.

other subnational government sectors.

Fig. 5 shows that the provincial governments began to actively respond to the national consensus and started introducing policies that were conducive to the development of the NEV industry since 2013. Notably, Guangdong and Shanghai were among the first to issue NEV policies, and play leading roles. In 2013, four ministries (Ministry of Finance, the Ministry of Science and Technology, the Ministry of Industry and Information Technology and the National Development and Reform Commission) of the State Council ascertained the list of the first batch of pilot cities promoting NEVs. Meanwhile, province governments introduced a substantial amount of policies that mainly focused on application promotion and financial subsidies in 2014. The purpose of these policies was to promote the production and sale of NEVs. From 2014 to 2016, the policies focused on application. The number of application policies in 2015 dropped slightly whereas the number of industrialization polices rose compared with that in 2014.

The classification of provincial NEV policies is shown in Fig. 6. At this stage, the policies of China's NEV focused on the formation and development of industry and paid more attention to the acceptance and use of NEVs. The Chinese government tried to cultivate the NEV market. Under this circumstance, the number of R&D policies was relatively small. It can be seen that provincial policy instruments are evenly applied in terms of industrialization and R&D. For application, the number of supply-side and demand-side policies is relatively large. These policies directly stimulate buyers and sellers. Considering their specific circumstances, provinces refine and promote the implementation of national policies. However, compared with national policies, provincial R&D policies are far rarer, which indicates that national policies are insufficiently specific and that in some respects at the least, provinces lack initiative.

Figs. 7 and 8 are the sequence chart for implementation of NEV policies in Guangdong and Jiangsu province, respectively. Guangdong was one of the first provinces to issue NEV-related policies of these types. The province's development plan for electrical vehicles was released in 2010. The purposes of the policies therein were comprehensive to include enterprises and consumers. Some policies were intended to promote NEV industrialization and application, whereas others centered on NEV R&D. All application policies concerning NEVs were published in the first six months of the past three years in Guangdong Province. During the initial stage, policies mainly focused on industrial planning and supply-side project construction. After the market gradually formed,

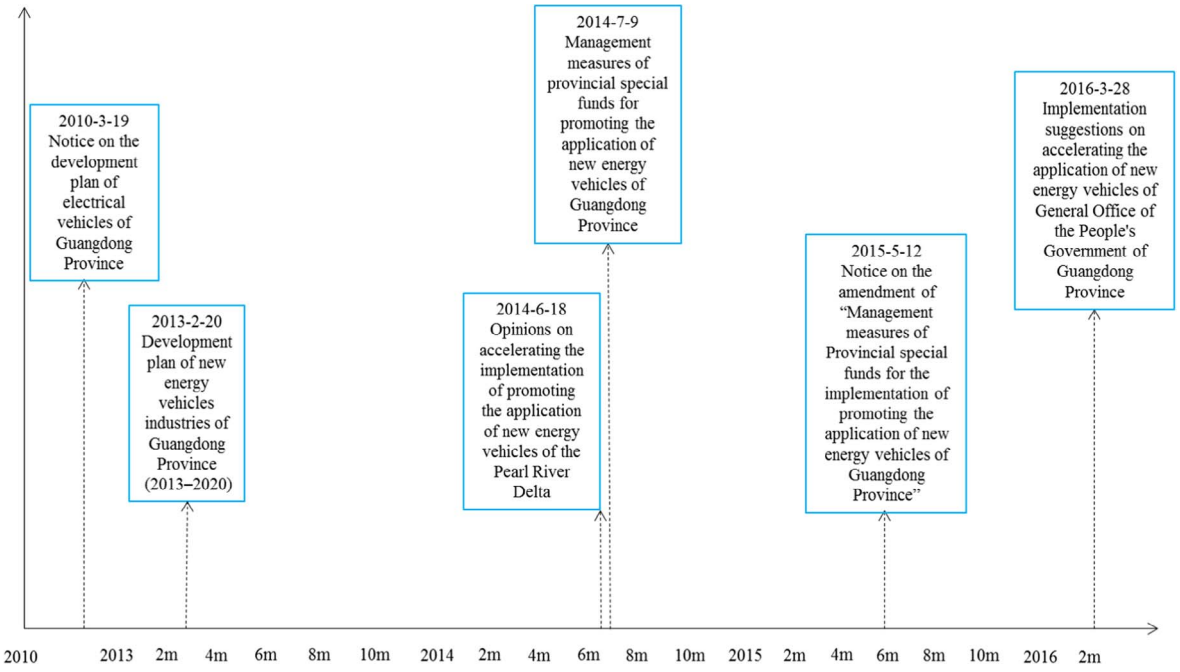

Fig. 7. Sequence- chart for implementation of NEV policies in Guangdong Province.

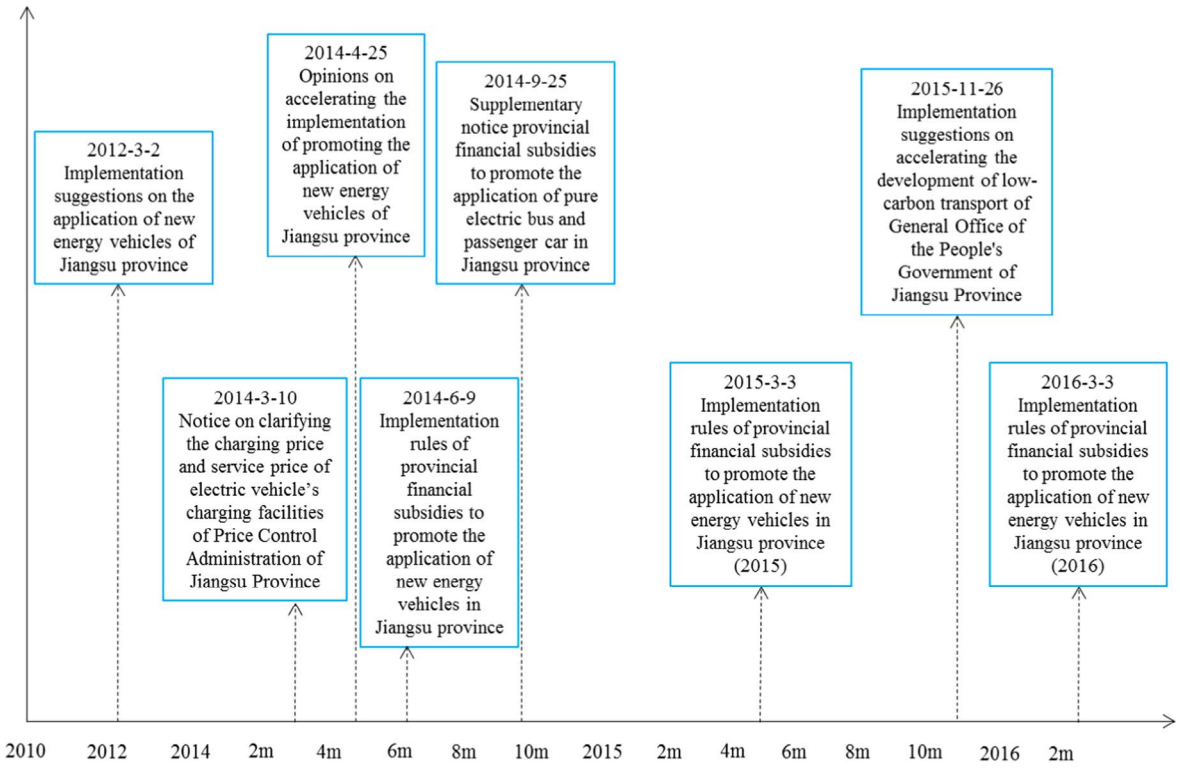

Fig. 8. Sequence-chart of implementation of NEV policies in Jiangsu Province.

policies mainly focused on financial support to increase the demand for and promote the application of NEVs.

Jiangsu is one of the regions with the most potential for development in China's automobile industry. A large number of NEV companies or research and design institutes gather there. In 2014, the production and sales of NEVs in Jiangsu Province ranked first in the country. At the same time, the ambient air quality in Jiangsu Province was generally poor. Jiangsu Province then adopted a multi-subsidy policy to stimulate the application of NEVs; the focus of this policy was to promote the purchase and use of NEVs, especially for first-time buyers, and reduce the environmental pollution caused by new vehicles.

Number of NEV policies issued by Beijing and Shanghai is shown in Figs. 9 and 10, respectively. As the capital city, Beijing has a relatively large population density and a more developed economy; consumers there have a greater rigid demand for vehicles. Beijing's policy measures are diverse and comprehensive, covering all the aspects of NEVs. In particular, the “exemption from traffic restriction” policy and the introduction of various subsidy policies prompt NEVs to gradually become the preferred solution for users and families having a rigid need for a second car. In addition, the well-behaved demonstration and operation in Beijing's public sectors also enabled consumers to gradually recognize NEVs.

To encourage individuals and institutions to purchase and use NEVs, Shanghai developed a three-year plan to promote the application of NEVs (from 2013 to 2015), carefully managed the development of NEVs and introduced more flexible incentive policies with local characteristics. These measures were introduced to increase residents' demand for NEVs, support construction of a charging infrastructure, standardize the process of purchase and usage, promote the development of the timeshare rental business, and create an environment for the development of the NEV industry. In 2013, Shanghai becomes one of the pilot cities. Afterwards, Shanghai's government issued a substantial amount of policies that mainly focused on application promotion and financial subsidies.

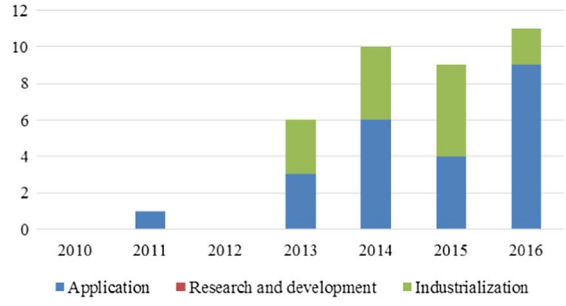

Fig. 9. Number of NEV policies issued by Beijing.

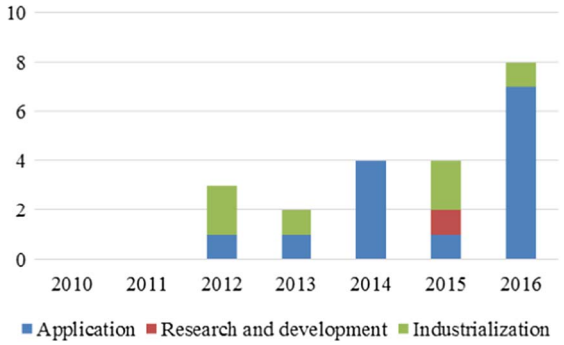

Fig. 10. Number of NEV policies issued by Shanghai.

These policies in 2014 aimed at promoting the production and sale of NEVs. As a result, the number of application policies slightly decreased and industrialization polices rose compared with that in 2014.

Although the policy purposes of the four provinces and municipalities have different emphases, they have mainly applied demand-side and supply-side policy instruments, and used financial subsidies to stimulate the production and sales of NEVs. These policies, which are more targeted, are issued from one to two years later than national policies. Other provinces and municipalities have followed these four provinces in issuing policies, but the strength of their policies is generally weaker.

5.2. Municipal policies for NEVs

Under the guidance of provincial governments and national policies, municipal governments now launch their own NEV policies, depending on their local situations. We collected, summarized, and analyzed 222 policies issued by 86 cities (see Figs. 11 and 12).

Municipal policies were mainly issued in 2014 and 2015. From the state to the province and to the city, policies gradually changed from macro-plans to implementation programs. For the application of policy instruments, provincial and municipal policies are broadly similar. Between 2013 and 2016, the top five cities for NEV sales in terms of volume were Shanghai, Beijing, Shenzhen, Qingdao, and Tianjin (see Fig. 13).

The volume of NEV sales in Shanghai, Beijing, and Shenzhen greatly exceeds the volume in other cities. The policies of Beijing and Shanghai were analyzed in the previous section and this section focuses on Shenzhen.

Fig. 14 is the sequence chart of implementation of NEV policies in Shenzhen. Shenzhen is active in the development of China's new energy industry. As early as 2009, Shenzhen Municipal Government established a development plan for the entire new energy industry. Before 2015, among the new energy industry support policies promulgated by Shenzhen Municipality, NEV were often mentioned. Following this, the Shenzhen government, as a special economic zone, based on the basis of its own local situation, implemented measures for the popularization and application of NEVs. Regulating the restrictions on car purchasing is intended to encourage residents to purchase NEVs. Additionally, new residential construction projects are required to be equipped with electric vehicle charging infrastructure. Shenzhen has put considerable effort into NEV policies, which cover numerous and diverse aspects of the industry and create a favorable environment which is conducive to the rapid development of the industry in the future

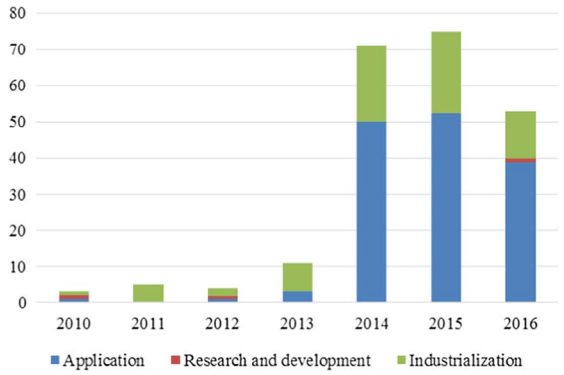

Fig. 11. Number of municipal NEV policies in China.

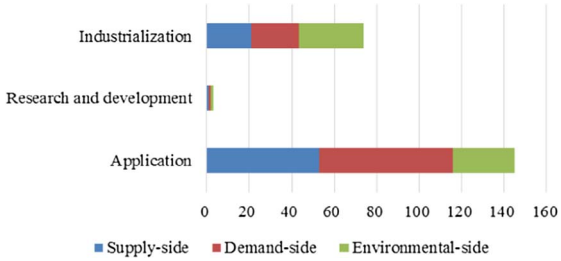

Fig. 12. Classification of municipal NEV policies.

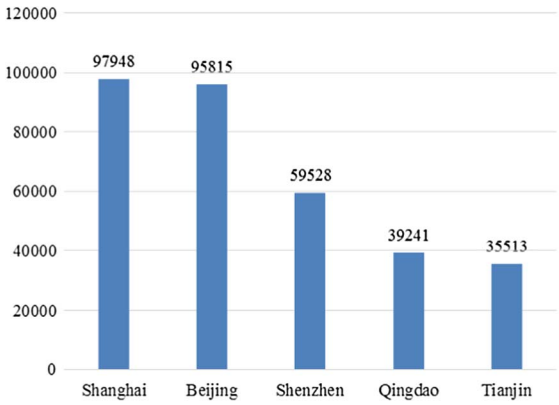

Fig. 13. Top five cities for NEV sales (2013–2016).

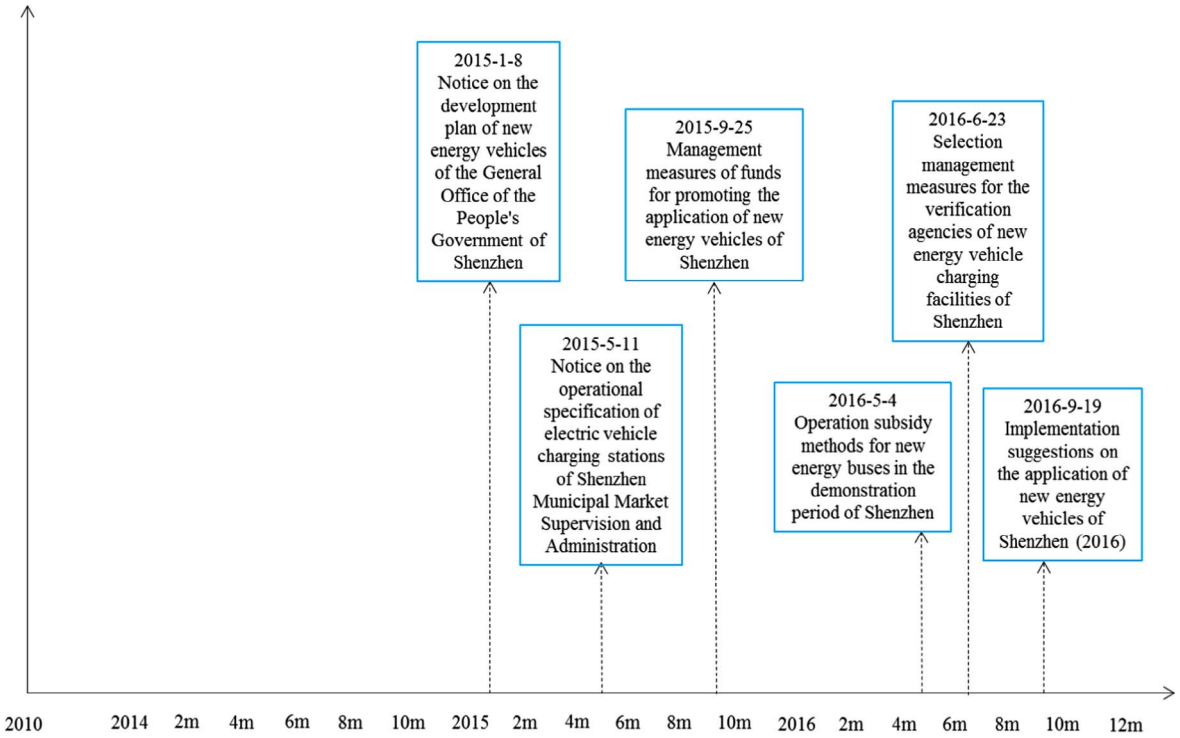

Fig. 14. Sequence chart of implementation of NEV policies in Shenzhen.

Table 3
Standard allowances for promoting the application of pure electric passenger cars and plug-in hybrid passenger cars (extended range) (units: 10,000 yuan/vehicle).

Vehicle types	Driving range of pure electric vehicles (R, mode-test, kilometers)			
	100 ⩽ R< 150	150 ⩽ R< 250	R⩾ 250	R⩾ 50
Pure electric passenger cars	2.5	4.5	5.5	/
Plug-in hybrid passenger cars (with extended range)	/	/	/	3

6. Comparative analysis of subsidy policies

6.1. Comparison of subsidy policies for NEV types

On April 29, 2015, the Ministry of Finance, Ministry of Science, Ministry of Industry and Information Technology, and the National Development and Reform Commission jointly released the "Notice on financial supportive policies to promote the use of new energy vehicles (2016–2020)." These departments noted that subsidies for 2017–2018 would decrease by 20%, compared to 2016 subsidies. In addition, subsidies for 2019–2020 would decrease by 40% (compared to 2016 levels). The policy implementation period is 2016–2020. The four ministries plan to judiciously adjust subsidy policies on the basis of technological progress, industrial development, the application promotion scale, cost changes, and other factors. Details of the allowances for various NEV types are detailed below (see Tables 3 and 4).

Standard allowances will also be provided for promoting the application of pure electric vehicles, plug-in hybrid vehicles (with extended range), and other special vehicles and trucks.

Buses with a length of 10–12 m (i.e., standard buses) have been granted 1800 yuan per kilowatt-hour, depending on battery capacity. Buses of six meters in length or shorter have been granted a 0.2-fold standard allowance. Those longer than six meters and shorter than or equal to eight meters will receive a 0.5-fold standard allowance. Buses longer than eight meters and shorter than or equal to 10 m will be granted a 0.8-fold standard allowance. Finally, buses longer than 12 m and double-decker buses have been granted a 1.2-fold standard allowance. Furthermore, the allowance standards are to be further refined, depending on the product category and performance index (see Table 5).

The preceding section lists the latest national policies concerning subsidy standards for different types of NEVs. On the basis of the aforementioned subsidy standards for the four vehicle categories shown above, we can conclude that, in China, out of all the new energy passenger cars, fuel cell passenger cars have been awarded the highest subsidies because certain difficulties concerning the technologies used in fuel cell vehicles still remain. However, and despite these difficulties and because they are an ideal NEV type, government support for fuel cell vehicles is the greatest.

Whether or not they are passenger cars or buses, subsidies for pure electric vehicles are greater than those for plug-in hybrid vehicles. This is because plug-in hybrid vehicles, being transitional products between conventional vehicles and NEVs, can meet consumer needs but do not represent the NEV industry's ultimate development direction.

Generally, the longer the driving range of a pure electric vehicle, the greater will be the subsidy amount. However, a slight difference persists; the difference in subsidies for passenger cars decreases as the driving mileage of pure electric vehicle increases. In contrast, the difference in subsidies for buses increases as the driving mileage of pure electric vehicle increases.

In conclusion, government policies are particularly supportive of certain types of vehicles. First, fuel cell vehicles (passenger cars, buses, or trucks) are given uniform subsidies that are significantly greater than those of other types of NEV. Second, subsidies are more often awarded to long-range pure electric vehicles than to short-range plug-in hybrid vehicles and standard-range pure electric vehicles.

6.2. Comparison of subsidy policies of different regions

On the basis of national policies, provincial and municipal governments have issued corresponding local subsidy standards. The

Table 4
Standard allowances for promoting the application of pure electric buses and plug-in hybrid buses (units: 10,000 yuan/vehicle).

Vehicle types	Energy consumption per kilometer per kilogram (E_{kg},Wh/km kg)	Standard vehicles (10 m < length ≤ 12 m) Driving range of pure electric vehicles (R, Isokinetic method, kilometers)					
		6 ⩽ R< 20	20 ⩽ R< 50	50 ⩽ R< 100	100 ⩽ R< 150	150 ⩽ R< 250	R⩾ 250
Pure electric buses	$E_{kg} < 0.25$	22	26	30	35	42	50
	$0.25 \leqslant E_{kg} < 0.35$	20	24	28	32	38	46
	$0.35 \leqslant E_{kg} < 0.5$	18	22	24	28	34	42
	$0.5 \leqslant E_{kg} < 0.6$	16	18	20	25	30	36
	$0.6 \leqslant E_{kg} < 0.7$	12	14	16	20	24	30
Plug-in hybrid buses (with extended range)		/	/	20	23	25	

Table 5
Standard allowances for promoting the application of fuel cell vehicles (units: 10,000 yuan/vehicle).

Vehicle types	Standard allowances
Fuel cell passenger cars	20
Fuel cell light buses or trucks	30
Fuel cell large or medium-sized buses or heavy trucks	50

year 2016 is the first year of the "13th Five-Year Plan", and we have put together the subsidy policies on the purchase of NEVs. In Fig. 15, the red area represents places whose local subsidies are not less than the national subsidies; the yellow area represents the places in which the ratio of local subsidies to state subsidies is greater than or equal to 0.5 and less than 1; the green area represents the places in which the ratio is greater than 0 and less than 0.5; and the blue area represents the places whose local subsidies do not refer to national standards or have not yet been determined (e.g., Xinjiang). Visibly, some car buyers enjoy national, provincial and municipal subsidies at the same time.

As shown in Fig. 15, regional differences in NEV subsidy policies exist. Provinces and cities whose subsidies were superior to those of national subsidies are mostly located in Central China and East China. Different subsidy proportions indicate that the stages of development of the NEV industry differ throughout China, which in turn might lead to differences in the effects of the policies.

6.3. Comparison of subsidy policies in different countries

The financial subsidy policy in China mainly includes financial incentives for NEV manufacturing enterprises in the production preparation period. Moreover, subsidies are provided to consumers through three ways: (1) directly transferred to the consumers; (2) NEV production enterprises advance payment for consumers; and (3) NEV sales organizations advance payment for consumers. Before 2012, the emphasis was on the public sector (e.g., bus operation subsidies and subsidies for purchasing official vehicles). The

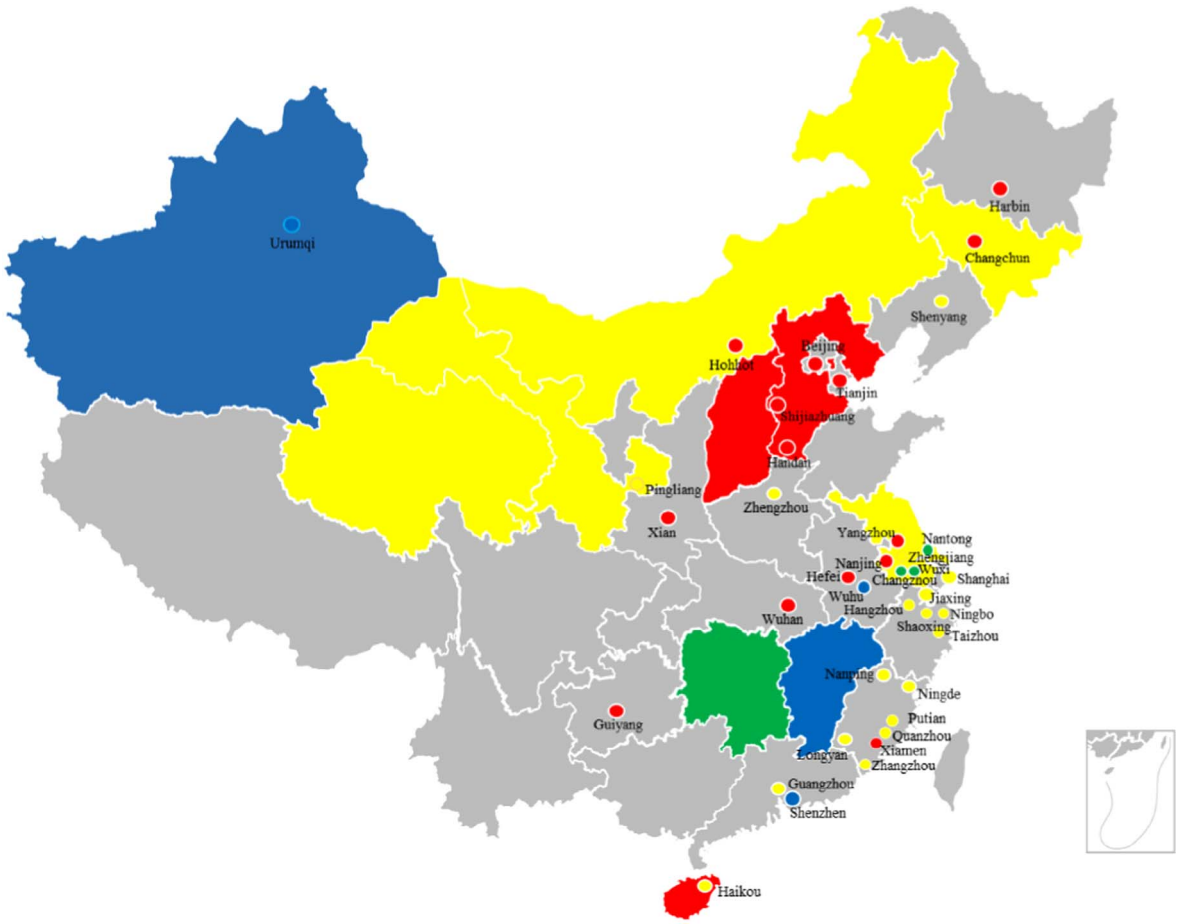

Fig. 15. Regional differences in subsidy policies.

Table 6
Preferential policies to promote the development of electric vehicles in different countries.

Country	Subsidies for car purchases	Tax reductions	Incentives
United States	Subsidies covering 10% of the price from the government (no more than US$4000) per vehicle. State and local governments may offer additional subsidies, for example, US $500 in Los Angeles County per vehicle	Car buyers can receive $2500 to $7500 federal tax benefits depending on the size of the battery	Electric cars do not need to pay the parking fees and bridge maintenance fees and in some states, the cars can enjoy free charge and drive on the fast lanes and carpool lanes
Japan	The central government grants local governments JPY¥1,236,000 for each small electric car. The central and local governments each grant private industry 1/5 of the price for each electric bus. Half of the difference between the price of electric vehicles and internal combustion engine vehicles of the same level is supported by government subsidies.	Motor vehicles tax, commodity tax, and license tax are approximately halved; tax breaks for purchasing electric cars (acquisition tax): ordinary passenger cars (3–6%), private vehicles (3–5%), business vehicles (1–3%). Land tax for fuel supply stations is halved.	Government agencies spearhead purchases of electric cars.
France	Car buyers can receive € 750–6300 discount according to the displacement.	Providing a certain percentage of tax incentives for the electric car manufacturers.	Electric cars can be parked for free in parking lots and without penalty at roadside, and some road sections only allow electric vehicles.
Germany	Buyers of plug-in hybrid electrical vehicles will receive a subsidy of € 3000 and buyers of pure electric vehicles will receive a subsidy of € 4000.	Electric vehicles are to be exempted from motor vehicles tax in 10 years. Companies devoted to R&D on electric cars can enjoy a 5-year tax exemption.	68% of charging stations are free of charge, only a few charging stations charge parking fees or charging fees.

public and private sectors were later given equal priority. The ratio of purchase volumes for the public sector to the private sector is approximately 2:1.

In the countries featured in Table 6, subsidies for consumers now extend to the post-purchase period, as well as to the purchase itself. Direct subsidies supplied to the NEV car manufacturers are inferior. These incentives are mainly provided through the tax system. For instance, Germany provides tax incentives or exemptions to electric vehicle manufacturers. Overall, the NEV subsidies in China are not inferior to subsidies in other countries. However, subsidy methods of other countries are more diversified and comprehensive.

7. Policy tendencies for NEVs

From the previous analysis of national, provincial, and municipal policies, we summarize the procedure for introducing NEV policies as follows:

First, policies regarding a development plan for the NEV industry were prioritized. This plan clearly defined the development objectives and the scope of financial support.

Second, policies for promoting NEV applications were implemented, including the following principal components:

(1) Procurement plans for NEVs, including buses, taxis, and government vehicles.
(2) Plans for the purchase of NEVs by specific individuals or units.
(3) Plans for constructing supporting infrastructure, such as charging stations.
(4) A clear division of work for those individuals necessary to the overall policy.

Third, specific subsidies for NEVs were appropriated by various departments of finance, which in turn clearly defined subsidy objects and application specifications.

Fourth, according to each government's situation, policies or programs were launched to promote the development of NEVs.

Finally, to correct problems that occurred during the promotion, steps were taken to improve management systems, set industry standards, strengthen supervision, and verify the effective implementation of subsidies. All these steps were beneficial to the implementation of NEV policies and the healthy development of the market.

We conclude that the implementation of NEV policies in China consisted of a "plan-pilot-promotion-subsidy-development" process. Initially, strategic planning was mainly determined on the basis of the condition of the entire vehicle industry and the goals of energy saving and emission reduction. This was followed by the government determining a development route, establishing a guiding ideology for development, selecting appropriate pilot cities, and using a "public transportation-private use" approach to promote and encourage the use of city bus systems. The government also became heavily involved in the procurement of NEVs, and in motivating individuals with financial subsidies. Once the consumer market gradually formed, it became necessary to reinforce the construction of the charging infrastructure and to use innovative financial instruments to support the NEV industry, in order to accelerate the development of that industry.

Our research indicates that the NEV industry will exhibit the following development trends:

(1) The back slope of the subsidy mechanism shows that the government has transformed itself from being policy-driven to being both policy- and market-driven. This situation will continue and gradually intensify.
(2) A lack of policies regarding infrastructure construction and the deficiencies of infrastructure is the key factor that currently restricts the industry's development. With China's rapid urbanization process, the infrastructure construction provides a good opportunity for the development of charging facilities (Fan et al., 2017). Since 2015, China has issued policies that support the construction of charging facilities. We believe that these policies will be more systematic in the future.
(3) In China, the integration capability, battery management systems, and thermal management systems of batteries are considerably inferior to those of developed countries. Incomplete statistics report nine NEV fire incidents, all of which resulted from systematic malfunctions. Thus, since 2015, China has issued policies mandating stricter safety checks. Such policies will become more comprehensive to ensure personal safety and NEV reliability.
(4) The number of NEVs has now attained a level at which battery recycling has become an urgent issue. In January 2016, the Chinese government issued the first policy governing waste battery recycling. This policy encourages production enterprises to proactively recycle batteries by offering subsidies. This will also be the orientation and direction of upcoming policies.
(5) Advertisements and demonstrations of NEVs in pilot cities emphasize bus and car rental facilities to a greater extent, because these types of vehicles are concentrated in urban areas. The availability of sufficient vehicle stocks means achieving policy targets is possible. However, the amount of influence exerted by the public sector on the private sector is not as great as predicted. Factors affecting the purchase and utilization of NEVs mainly include acquisition cost, usage cost, vehicle performance, charging environment, and additional features. A greater number of preferential policies for private use will therefore be introduced.

8. Policy recommendations

Overall, the development of the NEV industry in China has mainly been driven by policies. We propose the following five policy recommendations to solve problems in the NEV industry and the Chinese government's policy approach:

(1) A systematic, continuity and predictability approach must be strengthened. The development of NEVs involves multiple levels of government across a range of departments. Departments tend to perform management functions and services on the basis of their own perspectives and priorities, resulting into an overall lack of planning and coordination. Furthermore, central and local governments have not effectively cooperated. For example, in the first half of 2016, no new central or provincial NEV policies were issued for several months. Consequently, some NEV manufacturers worried that policies might change, and thus, they temporarily ceased operations. Furthermore, consumers were unable to register their vehicles. Moreover, following central government policy announcements, some cities responded positively but some cities did not respond at all. Even when certain supporting policies were issued, they deviated from the principal implementation program. Thus, the central government should design a reasonable policy system on a macroscopic scale and guarantee the sustainability and predictability of those policies. Joint coordination mechanisms should also be strengthened. Central government and local governments must form joint committees to design strict evaluation and replacement mechanisms.
(2) Policy instruments must be diversified. Financial subsidy policies are usually employed and strengthened on a step-by-step basis, from central government to local government. A generalized system leads to preferential treatment and thus, a lack of diversity of incentive results. This lack of variety in policies could easily result in an unhealthy dependence on the part of manufacturers and a lack of impetus for innovation. Thus, market orientation will not be achieved. We suggest that the government should optimize the current subsidy policy to include different subsidy amounts for lowering energy consumption, developing technology, and lowering costs. This would encourage enterprises to engage in independent innovation.
(3) To guarantee product quality, NEV R&D must be strengthened. Although central government departments support NEVs through technological and innovation projects, the intensity is greatly inferior to that of purchase subsidies. Due to these factors, vehicles as a whole and their essential components lack quality. To promote breakthroughs in NEV technologies, the government should combine subsidies and rewards in its policies to encourage technological innovation. Furthermore, to perfect the financial support system, China will need to attract large-scale enterprises, financial institutions, and social capital, all of which are essential to the increasing investment in innovative products and essential technology.
(4) Electricity infrastructure construction must receive greater focus and a more favorable environment should be provided for accelerating the development of the industry. A severe shortage of electricity infrastructure would seriously restrict NEV industry development. Solving charging problems for residents is vital if the general public is expected to use NEVs. At present, Shenzhen and other cities have started supporting the construction of charging facilities. Problems concerning charging standards, site selection, selection of electricity charging modes, and power system loads should be fully considered. Moreover, ensuring heavy investment in the early stages of infrastructure construction, long-term investment payback periods, and the profit patterns of service suppliers should also be the overarching aim of NEV infrastructure policies.
(5) Preferential policies for private users must be prioritized. On the basis of the domestic and international experience, the impact of subsidies as a direct incentive is short-term and has limitations. Once the market for NEVs increases to a certain extent, consumer demand will diversify. Therefore, government departments should be farsighted in their overall planning. They should create a favorable industrial environment that focuses on land use, the transformation of existing gas stations, and the construction of charging stations in residential areas. At the same time, the government should develop preferential policies and introduce more

innovative incentives related to electricity charges, parking fees, annual vehicle inspection fees, highway tolls, insurance expenses, vanity license plates, parking space allocation, and car purchasing and driving restrictions.

9. Conclusions

As a major breakthrough that could mitigate the effects of energy crises and improve the environment, NEVs have been afforded serious attention from the Chinese government. However, the NEV market share is still rather small. With the support of recent policies, the Chinese NEV industry has entered a period of rapid development. However, existing problems should not be ignored. Scholars at home and abroad increasingly notice the development policies of the Chinese government toward NEVs. However, the level of multidimensional research and government hierarchy is not enough.

This study used policy instruments and purposes as an entry point, in order to discuss the current status of NEV industry development and to analyze policy-development logic and future trends. We report on the connections between practical problems and policy oversights; in further propose suggestions for policy improvements. Future policies should adjust the current mechanisms with regard to financial subsidies, infrastructure construction, R&D, the recycling of batteries, and private purchase regulations. Moreover, the top-level policy-development system, policy diversity, and the extent and methods of R&D policies must also be perfected.

Although we have provided a new perspective toward the analysis of NEV policies in China, further study on this topic is necessary. This study mainly focuses on an extensive analysis of policy texts. We intend to analyze the effects of government policies when NEVs achieve a certain market share, in order to obtain further conclusions.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.tra.2018.02.012.

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